Beyond Line-of-Sight Information Dissemination for Force Protection

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Abstract—Force protection capabilities have emerged as necessary for operations such as Village Stability Operations and Forward Operating Base security. Current Force Protection Kits include a rich set of sensors that can be monitored from a core operator station. This paper describes ongoing research to extend the reach of Force Protection capabilities as part of an integrated, network-centric system to protect mobile troops on patrol, to include sensors beyond the organic Force Protection perimeter, and to enable the automated, selective transfer of information to and from kit locations. These extended Force Protection capabilities are enabled by a highly-mobile, vehicle mounted information management system providing beyond line-of-sight publish-subscribe capabilities, sensor data archiving, video storage and retrieval, and data ferrying across long distances.

Index Terms— Information Management, Force Protection Kits, QoS Management, Beyond Line-of-Sight Communication.

I. INTRODUCTION

In modern asymmetric warfare, military personnel are frequently engaged in non-combat, but dangerous, operations in semi-permissive environments, i.e., environments without active combat but in which a threat to personnel exists. Operations such as Village Stability Operations (VSO), surveillance, peacekeeping, patrol, and police operations do not typically involve active combat, but do involve the constant and persistent threat to personnel. Improved surveillance and situation awareness through advanced off-site monitoring and rapid access to high quality imagery and video would significantly augment the Force Protection and security at forward operating bases and in VSOs for Special Operations Forces.

This paper describes ongoing work to advance Force Protection capabilities using emerging tactical information management (IM) platforms that support networked beyond line-of-sight (BLOS) communication in dynamic environments. These capabilities have the potential to extend the reach of existing Force Protection Kits, to enhance the mobility and portability of Force Protection monitoring, and to better support troops on patrol.

We have been developing *Marti*, an advanced IM platform that provides a publish-subscribe-query interface for BLOS information exchange between varying numbers of sensors and tactical war fighters in tactical network environments. Marti has the potential to improve situation awareness and Force Protection for tactical users with the following advanced capabilities:

- IM services for Force Protection Kits, extending the reach of current Force Protection capabilities and supporting the archiving, filtering, and dissemination of real-time information over a tactical network.
- Bandwidth-efficient tactical IM services on ultraportable devices, which provide networked situation awareness to mobile troops, such as troops on patrol, and remote tasking of sensors for Force Protection.
- Video archival and bandwidth-efficient reachback to command centers behind the tactical edge, such as Forward Operating Bases (FOBs), Air Operations Centers (AOCs), and Marine Operations Centers (MOCs).

The contributions of this paper are the following:

- A presentation of the design and capabilities of our Marti information management system and its benefits in Force Protection scenarios.
- An explanation of the limitations of current Force Protection Kits and the presentation of our extensions to support beyond line-of-sight information exchange in dynamic, resource-constrained tactical environments.
- A description of a situation awareness tool that runs on Android tablets and smartphones that, in conjunction with Marti, enhances troops' mobility, access to Force Protection information, and reachback to command and control.

The rest of this paper is organized as follows. Section II describes the current state of Force Protection Kits. Section III introduces the Marti IM platform. Section IV describes our ongoing work to enhance Force Protection using Marti IM services. Section V describes some related work. Finally, Section VI provides conclusions and next steps.

II. FORCE PROTECTION KITS

Force Protection consists of measures taken to prevent or mitigate potentially hostile threats against troops, personnel, or a populace. Force Protection is facilitated by *Force Protection Kits (FPKs)*, such as the Cerberus Force Protection Suite [4], [16]. FPKs consist of sensors such as thermal infrared, optical, and motion detection sensors, radar, and breakwire trigger sensors that can be placed in a perimeter, such as around a

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14. ABSTRACT

Force protection capabilities have emerged as necessary for operations such as Village Stability Operations and Forward Operating Base security. Current Force Protection Kits include a rich set of sensors that can be monitored from a core operator station. This paper describes ongoing research to extend the reach of Force Protection capabilities as part of an integrated, network-centric system to protect mobile troops on patrol, to include sensors beyond the organic Force Protection perimeter, and to enable the automated, selective transfer of information to and from kit locations. These extended Force Protection capabilities are enabled by a highly-mobile, vehicle mounted information management system providing beyond line-of-sight publish-subscribe capabilities, sensor data archiving, video storage and retrieval, and data ferrying across long distances.

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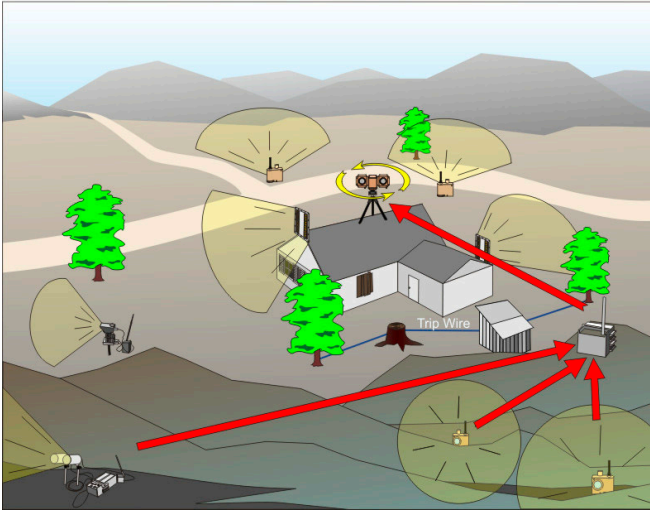
Fig. 1. Deployed FPKs establish a perimeter, e.g., around a safehouse, and deliver sensor information to a central post.

Fig. 2. Marti provides beyond line-of-sight information dissemination through QoS-managed tactical radio links.

safehouse (Fig. 1). They are deployed to protect forces engaged in a variety of non-combat situations with potential threats, such as VSO, FOB security, overnight rest, or persistent surveillance.

FPKs are real-time systems that deliver the sensor data to an operator as events occur. Each system delivers video digitally and has an approved DoD standard for command and control (e.g., Cursor on Target, CoT [13], or SEIWG 0100 [1]).

III. THE MARTI IM PLATFORM

We have been researching and prototyping *Marti*, an advanced tactical information management system shown in Fig. 2. Marti provides a publish-subscribe information broker that can be hosted and rapidly deployed on manned or unmanned aircraft, on high altitude balloons, or in command and control centers, such as FOBs. Marti provides beyond line-of-sight information brokering for tactical users, through standardized information formats and interfaces, using existing applications and devices, including Android-based devices and a variety of tactical radios. Because it is based on a publish-subscribe model, information producers (publishers) are decoupled from information consumers (subscribers), meaning users can connect dynamically and register their interest in future information that might become available or query for archived information. It can also be optimized to the bandwidth available, to meet low-bandwidth requirements of tactical operations.

Marti is service-based and consists of the following core components and services (shown in Fig. 3):

- AFRL's Fawkes information broker for matching published information to subscribers based on type, characteristics, and content [15]. The IM services include a Submission Service, a Repository Service, and a Dissemination Service [6].
- The Submission Service accepts published messages, archives them, and forwards them to the Repository Service and Information Brokering Service. The submission service also performs traffic shaping when applicable.
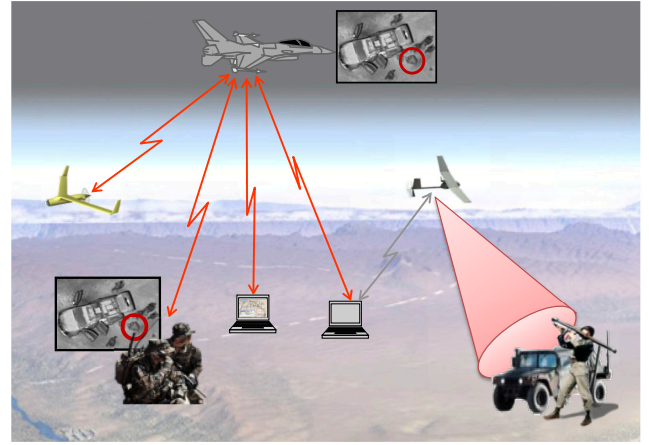
- The Repository Service archives information and services queries for past information by extracting and filtering information from the archive (a PostGIS geospatial database).
- The Information Brokering Service (Info Broker) manages the subscriptions (i.e., which subscribers are subscribed to what information types) and guides information dissemination (i.e., to which subscribers should each information object be sent).
- The Dissemination Service controls the information that is transmitted to each subscriber.
- Quality of Service (QoS) management features for prioritizing brokering and dissemination operations, managing shared and constrained bandwidth, and adapting data rate, size, and formats to the available bandwidth [5], [11].
- A Web Service interface that provides an HTTP request/response interface for viewing and retrieving ar-
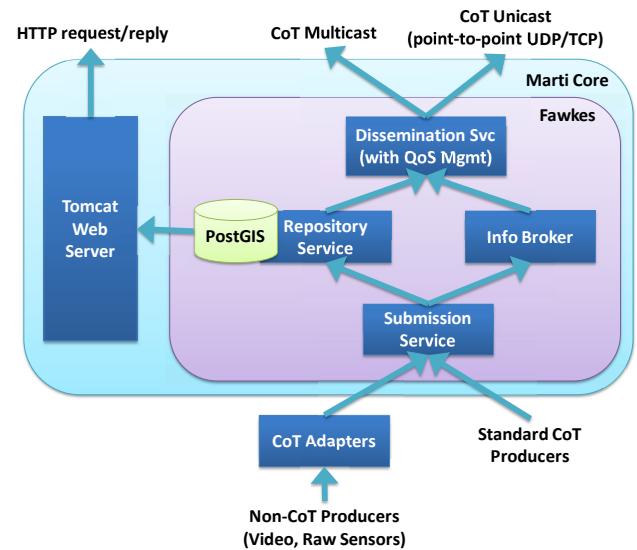

Fig. 3. The Marti architecture provides information brokering and QoS management through CoT and Web Service interfaces from existing military devices.

chived information and manipulating the behavior of the system (e.g., system configuration).

Marti improves situation awareness to tactical war fighters, by providing the following IM features:

- Automatic discovery of platforms and services.
- Automatic discovery of new information types.
- Near real-time notification of time-critical information.
- Archived information access using on-demand query.

Information discovery and client connection is simple and dynamic. Marti uses standards-based information formats, a Web Services interface, and adapters to work with existing application interfaces.

In ongoing sets of live-flight experiments, Marti has been hosted on multiple platforms, including

- A high-altitude (up to 85,000 feet) balloon serving as a surrogate High Altitude Long Enduring (HALE) unmanned platform.
- Sensor pods, such as the LITENING Pod [10] attached to existing aircraft.

More details about Marti, including its QoS features, are available in [5]. Marti provides extensibility, scaling to multiple users, and managed information dissemination currently unavailable to the users of Force Protection Kits. Current FPKs do not have the features of, or access to, IM capabilities. There is no current way to archive data on FPK systems, to route information for processing and analysis, or to access past or request future information through intuitive retrieval interfaces.

IV. ENHANCING FORCE PROTECTION WITH MARTI

Our current research is investigating and prototyping the extension of Force Protection Kits with enhanced IM services using Marti, to enable the following:

- Improved coverage of FPKs and greater dissemination of FPK-collected information in ways that enhance capability while being aware of bandwidth.
- Greater mobility of and access to FPK monitoring and control.
- Archival and dissemination of FPK and related information from the tactical edge to command and control centers.

A. IM-Enabled Force Protection Kits

Current FPKs provide real time surveillance and sensor data to a centralized core operator's station, as shown in Fig. 4. When unmanned, these systems still collect and provide intelligence on surveillance areas, but without an operator to view their output, this data is essentially lost. Integration of FPK capabilities with Marti will enable sensor information to be disseminated to multiple operators – who no longer need to be tethered to an operator station – and will allow for operators to review past detections and recorded media. Through the use of these images, video, and CoT events, better decisions can be made to allow for more successful mission planning and better response to threats.

Sensor detections and video are the common data elements that arrive at the core of the FPK system. These data feeds traditionally have different methods of storing information. CoT traffic might be stored as a flat file or within a database.
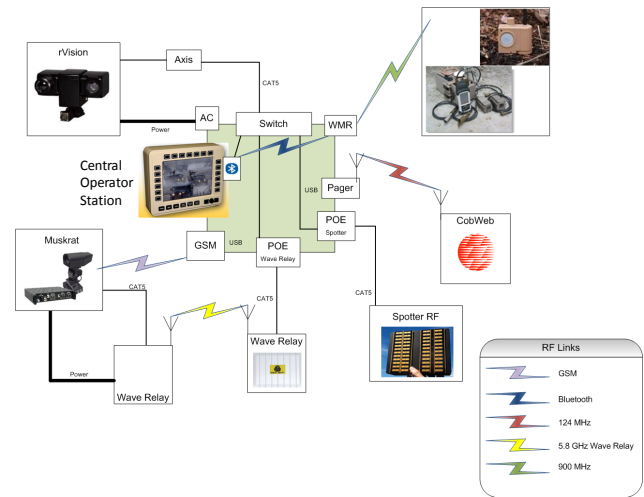

Fig. 4. The design of a FPK, with its multiple sensors, communication links, and centralized operator's station.

Video is typically saved as a file on a hard drive. These data elements are not combined, which makes it difficult to accurately interpret the information that the kit provided. Merging the two data formats together within the Marti repository will allow an operator to query the system and get an accurate picture of what the kits are telling them. Video and sensor hits are displayed harmoniously as if the operator was viewing the playback in real time, with the context of time, source and geography.

Storing multiple types of data in a common repository such as that provided by Marti also has the added bonus of allowing other systems to tap into the data source and process it. Systems that would enhance the FPK package, such as a pattern analysis tool, can easily be plugged into Marti to mine data from the repository and/or take additional actions based on pattern analysis triggers.

As an example, envision a situation where a FPK is set up to monitor a safe house while troops gather intelligence in the field, as shown in Fig. 5. Ground radar detects approaching vehicles, while unattended ground sensors detect foot traffic.
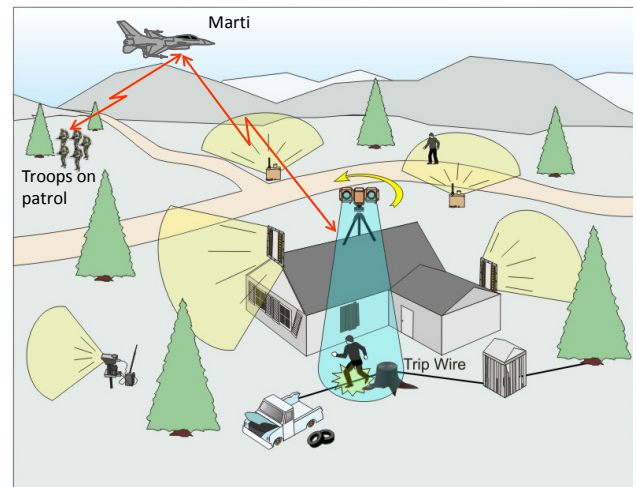

Fig. 5. Marti can untether troops from the FPK operator station, disseminating SA information to troops while on patrol.

Additional remote cameras record the entry of unknown individuals. Through the use of Marti, FPK events can be disseminated to the patrolling troops through handheld remote devices, such as those described in Section IV.B. The troops can get access to the SA data through queries on the Marti repository to determine if any of these items are cause for concern, using the same remote devices. The troops can make an intelligent decision as to whether entering the safe house is advisable, get SA about what awaits them there, and decide how to further proceed. This ability is most important to troops who may not have the personnel to monitor the FPK system (i.e., the centralized operator station) all the time, but still require the benefits of the system.

Integration of Marti with the FPKs can also provide intelligent mission planning. Through general queries, commanders can determine recent activity in a particular area and use this information to plan a successful operation. Data provided not only by the FPK, but also other assets that are accessible through Marti, can be combined to create a thorough overall picture of the operational area.

Using Marti, we envision an add-on to each kit that will tap into the central data hub of these systems, store the data and allow their native Command and Control software to play back the data so that it is viewable as it would be displayed in real time.

B. IM Services on Mobile Devices

Modern Android devices currently provide capabilities that a few years ago were only available on high end PCs. They provide an open and accessible platform upon which an intuitive interface can be created to display an operational picture of surrounding units, situations, and events. Ruggedized and secure versions suitable for military use [2], [8] are starting to emerge.

Providing access to IM services hosted on Marti through handheld devices would provide operators with situation awareness that will allow them to complete their duties more efficiently and safely and in devices that are readily available, inexpensive, and extensible.

We have been developing the Android Tactical Assault Kit (ATAK), an Android-based user interface and SA kit for Marti that runs on Android tablets and smartphones. ATAK provides an open API and government-owned technology that allows developers and organizations to develop on a common mapping API, as shown in Fig. 6. ATAK provides access to information published through Marti via a number of interfaces, as shown in Fig. 7, including Nine-Line briefs, CoT routing with waypoints, video, chat, subscriptions and sophisticated queries on the Marti repository. ATAK provides a basis for the full functionality and integration with Marti that we are performing to untether mobile users from the FPK console and to provide unprecedented access to and control of FPK sensors.

The handheld Android device is also useful to run other capabilities. Sensors included with an FPK can be controlled remotely to allow the user to observe an area without being in the immediate vicinity. The Android device can provide access to information ranging from simple detections generated by static sensors to more complex video sources that can be remotely controlled from the Android device.

Fig. 6. The Android Tactical Assault Kit application provides an intuitive Android interface to Marti with many user-friendly SA features.
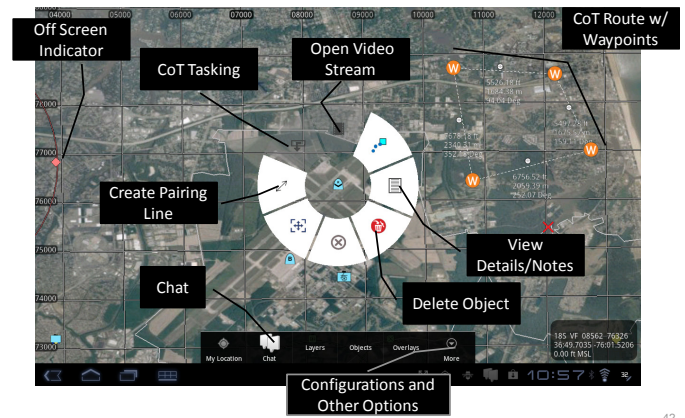

Fig. 7. The ATAK application provides access to information through several interfaces.

C. Video Archival and Management

Full-motion video (FMV) is a key aspect of some FPKs and is increasingly a requirement for DoD sensors. However, the reality of airborne long-range radio networks is that FMV delivery is not as straightforward as just pushing digitally-encoded video onto the network. Temporary line-of-sight obstructions, such as mountains, wing-flash (when an aircraft is turning), and other kinds of interference, can have a dramatic effect on the airborne network. A naïve approach to FMV that broadcasts a large volume of data all the time is undesirable from several respects. First, using bandwidth and power to broadcast when no one is listening provides no benefit. Second, there are a variety of uses for video, and not all of them require real-time delivery of video over the network.

We are developing capabilities in Marti to allow flexible exploitation of FMV, including storing video close to the sensor in a Marti server system and indexing the video periodically with a still image together with geographic and other metadata associated with that point in the video. Marti can provide interfaces that cover a broad range of use-cases for exploiting the FMV. A thumbnail browser allows users to visually identify portions of the video that are interesting, while using very little bandwidth. A web-based query interface

allows geographic and temporal queries, allowing users with minimal bandwidth to search through large volumes of data. Both of these interfaces allow a user to download only what is required. In some cases, the user may only need the metadata that describes high-level information about the sensor at particular times. Other users may want to see thumbnails of the actual sensor data over time. Still other users may want to see full-resolution and full-framerate video.

Marti also supports real-time re-broadcast of FMV. While the techniques described above are good for analyzing archives of pre-recorded video, soldiers in the field often need to see what is going on around them right now. Current approaches require a user to know (via out-of-band knowledge) which platform has the video they want to see. A better approach is to have users specify an area of interest, and have them automatically start getting video feeds from any sensor in the area. By using the Marti server and its IM features of establishing a subscription based on predicates such as location of an area of interest, we can tailor the real-time broadcast of video in a way that benefits the user. For example, if a user is on a disadvantaged link, Marti's QoS information shaping features can down-sample the video in either frame-rate or resolution, so that they get as much data as the link can handle.

Our goal for the video support in Marti is to have a flexible system that allows users to dynamically trade-off latency for quality, and doesn't waste bandwidth or other resources sending clients video that they don't want. Some users will be happy to watch FMV that is 20 minutes old. Other users want to see what is happening in real-time with no more than 30 seconds of delay.

The handheld devices described in Section IV.B will have limited available bandwidth, limited display sizes and resolutions, and will often require specific formats in order to use their on-board video hardware accelerator processors. Just about any video can be delivered and decoded on the devices, but combining Marti's QoS management and information shaping capabilities with information about the device's specific capacity and resources, Marti can deliver video in a form that can make use of the onboard hardware processors to make the devices more efficient and to support additional processing that is needed, such as a map and CoT parser.

D. Bulk Data Transfer

In an effort to collect operational sensor field data, store it, manipulate it, provide results to end users, and maintain command and control (C2) of embedded sensors, in-place, unattended sensors are leveraged that utilize ad hoc, mesh networks to support data-in-motion and remote data storage and access. These types of sensors are common among Force Protection technology. However, FPKs that support Force Protection for remote villages in an area of operations are often out of range of sufficient data links with larger FOBs and strategic assets. Terrestrial networks to such places are too expensive to put in place or too difficult to maintain and secure. SATCOM is sometimes an option, but SATCOM is relatively expensive and highly contended. We are developing capabilities for Marti to support *Data Ferrying*, a high-bandwidth, low cost, and safe way to transport information bi-directionally to and from remote areas, as shown in Fig. 8. A UAV with a short-range / high-bandwidth radio can both bring processed intelligence information to a remote area (e.g.,
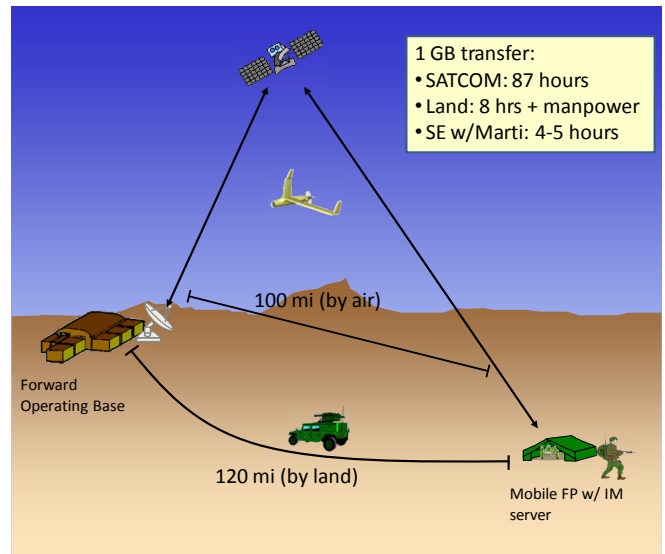

Fig. 8. Data ferrying can transport large amounts of data to and from remote deployments much quicker than SATCOM or transporting by land (which also exposes personnel to danger).

current satellite-based recon of the nearby area) as well as collect raw sensor data that has been archived locally for transport back to a larger organization for processing and analysis.

The general concept is that a UAV hosting Marti is flown over sensor systems such as an FPK. The UAV will then automatically ingest data, starting with data marked as high-priority and opportunistically ingesting other data, deliver any outstanding commands, and either carry data out to tactical users or back to operators at command centers. To accomplish these goals, unattended ground sensors (UGS) are placed in austere locations where they begin collecting and storing data. If the sensor of choice lacks these capabilities, then an intermediate device can be provided to act as both a warehouse for the data and a communications interface. The intermediate device can also provide data prioritization and collection, thereby weeding out undesirable data or false sensor interrogations and freeing up resources further down the sensor data management chain.

The information stored on the UAV can then be ferried back and forth between operators at the tactical edge and FOBs or other C2 centers out of the immediate area of operations. Ferrying a Gigabyte of Intelligence data by a UAV such as a Scan Eagle from a FOB to a mobile deployment 100 miles away can be done in less than five hours, versus eight hours by HMMWV (with extra manpower and exposure to threats) and 87 hours via satellite communications.

V. RELATED WORK

Other dissemination services are based on pub-sub. One that is similar to Marti in its goals is the Advanced Information Management Systems (AIMS) [3], which has been designed to use airborne platforms to extend network range beyond line-of-sight through publish, subscribe and query interfaces. While Marti supports a wide range of clients, AIMS limited its legacy clients to two technologies from which it was derived, the

Advanced Information Architecture (AIA) and the Joint Battlespace Infosphere (JBI).

The OMG Data-Distribution Service (DDS) [12] provides real-time information dissemination based on topic matching and a rich set of QoS parameters. However, DDS does not support archival (beyond a limited *history* function), does not support rich metadata matching, and does not support QoS management across multiple client connections that share bandwidth without application-level support outside of DDS.

FPKs are starting to emerge. Two that we are considering to target for this work are an FPK being developed by the Army Research Laboratory and the Cerberus FPK [4]. We expect Marti to work with a variety of FPKs.

Prior work in *message ferrying* can serve as a foundation for the data ferrying concept using Marti [7], [17]. Message ferrying is a routing technique for mobile ad-hoc networks (MANETs) that include power-constrained nodes. In message ferrying, the mobility of specific nodes, called *ferries*, is carefully controlled and known by the other nodes in the network. The ferries use store-and-forward routing, such as that used by delay tolerant networking [9], [14], to carry packets between other nodes. The nodes that are not ferries can turn off data transmission (and receipt) when the ferries are expected to be out of range in order to reduce power consumption. In our research, we will use similar principles, but at the application and information level. Our Marti nodes will serve as the ferries and move bulk amounts of information around, using pub-sub instead of packet-level routing.

VI. Conclusions

The Marti system has shown itself to be an important capability for supporting beyond line-of-sight communication and information exchange between tactical users in dynamic environments and operations. Simultaneously, FPKs have shown themselves to be important situation awareness tools for troops in semi-permissive environments. The combination of Marti's advanced information management, extensibility, and mobility with FPKs' wealth of sensors can provide more extensive situation awareness and hence protection to troops. Furthermore, the additional advanced capabilities that we describe herein – FPK access on handheld devices, video archiving and retrieval, and data ferrying – can greatly improve troops' mobility, access to information, and reachback to command and control and, therefore, unforeseen levels of protection and situation awareness.

Acknowledgment

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